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Acoustic-driven Oscillations of a Bubble in a Narrow Gap

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Abstract **–** The complex interaction of an acoustic cavitation bubble with a boundary is widely exploited in practical applications. In ultrasonic cleaning, acoustic cavitation is used to eliminate surface contamination and particulate debris following manufacturing. However, very little is known about the fundamental physics behind such processes. Furthermore, bubble collapse in the presence of two or more boundaries is considerably different than the traditional problem of collapse near a single rigid wall. In this study, we combine the complex pressure-driven dynamics of acoustic cavitation in confinement. We focus on the dynamics and jet development of an oscillating gas bubble ($R_0 = 50\,\mu$m) driven by a strong low-frequency acoustic field ($p_{ac} = 95\,$kPa and $f_{ac} = 20\,$kHz). Since inertial oscillations are responsible for most of the practical effects of acoustic cavitation, we select an acoustic driving frequency lower than the natural frequency of the bubble to demonstrate the transient response. We present results from compressible volume-of-fluid simulations with consideration of viscosity and surface tension conducted in the open-source framework of OpenFOAM. We find that the presence of a secondary opposing wall intensifies the jet velocities at collapse. We provide a detailed description of the flow inside the gap, particularly the complex interaction between flow deflected by the confining boundaries and the oscillatory driving pressure. By varying the gap height and the position of bubble inception, we observe significantly different bubble collapse dynamics across the considered parameter space, which can be categorised in three distinct jetting regimes according to relevant nondimensional parameters. We also demonstrate how an increased liquid viscosity alters the collapse mechanism and jet formation through a representative case. The results presented in this study have immediate consequences in acoustic cavitation applications involving confinement, since through careful choice of driving conditions and fluid properties, the desired behaviour to suit the application can be achieved.

Keywords**:** bubble dynamics; acoustic cavitation; confinement; narrow gap; OpenFOAM; volume-of-fluid